

SEMANTIC INTEGRATION OF BUSINESS APPLICATIONS ACROSS COLLABORATIVE VALUE NETWORKS

Athanasios Bouras¹, Panagiotis Gouvas¹, Dimitrios Kourtesis²,
Gregoris Mentzas¹

¹ *Institute of Communication and Computer Systems, National Technical University of Athens, 9, Iroon Polytechniou Str., 15780 Zografou, Athens, GREECE*
{bouras, pgouvas, gmentzas}@mail.ntua.gr

² *SEERC - South East European Research Centre, A Research Centre of the University of Sheffield and CITY Liberal Studies, 17 Mitropoleos Str, 54624 Thessaloniki, GREECE*
dkourtesis@seerc.org

If we try to increase the level of automation in Business-to-Business (B2B) Enterprise Application Integration (EAI) scenarios, we confront challenges related to the resolution of data heterogeneities, service discovery and process composition. In this paper, we propose the Enterprise Interoperability Ontology (ENIO) that provides a shared, common understanding of data, services and processes within B2B integration scenarios. ENIO consists of an Upper Enterprise Interoperability Ontology (Upper ENIO), which is based on the DOLCE-SUMO alignment, with extensions called facets that cover several dimensions of the EAI domain. Each facet contains a relative meta-model that utilizes widely adopted standards. Finally, we demonstrate the utilization of ENIO in a real-world B2B scenario across a franchisor-franchisees collaborative value network.

1 INTRODUCTION

Over the last couple of decades, we have witnessed an enormous increase in competitiveness among companies, leading towards the formulation of new business models and structures, such as virtual enterprises and collaborative value networks. These emerging business-to-business (B2B) formulas constitute alliances of member enterprises that come together to share skills or core competencies and resources to create economic value, which takes the form of knowledge, intelligence, products, or services. Value networks require significant systemic support that actually intends to automate part of the creation process, as well as the operation and the B2B interoperability of these enterprise models (Cardoso & Oliveira, 2005).

The goal of B2B Integration, which could be considered as a specialization of Enterprise Applications Integration (EAI), is to connect enterprises with their trading partners electronically through organized business event exchanges containing business data in order to conduct business between enterprises (Bussler, 2002), based on the integration and streamline of heterogeneous business processes across the collaborative value network.

Current industrial EAI, and B2B as well, trends and technologies, like Service-Oriented Architecture (SOA), Enterprise Service Bus (ESB), and Web Services technologies, are up to now quite mature. However, if we try to increase the level of automation in integration scenarios, we confront several problems and challenges, such as a) data and message level heterogeneities between interoperating services, b) insufficient search and discovery of published Web Services in a common registry, and c) inadequate Web Process composition with regard to the desired functionality and the operational requirements. The problem that still exists, which the traditional, syntactic integration technologies are weak to solve, refers to the formalization and the documentation of the semantics related to the interfaces and the data structures of the deployed Web Services. This lack of formal semantics regarding the applications and services to be integrated makes it difficult for software engineers and developers to manually interconnect heterogeneous applications impeding automation within EAI (Haller et al., 2005).

We claim that these needs impose the use and interpretation of semantics in EAI and that a semantically enriched approach will hopefully eliminate the problem of knowing the content and structure of information resources, as well as the structure and architecture of heterogeneous enterprise applications (Friesen et al., 2007).

In this paper, we propose the Enterprise Interoperability Ontology (ENIO), an EAI Ontology that captures and represents formally all entities involved in B2B EAI scenarios, i.e. data, services and processes and tries to address the EAI challenges mentioned above. ENIO comprises a foundational, upper-level EAI ontology, which is based on the alignment of DOLCE and SUMO, with quite a few extensions (which we call “facets”) that cover several dimensions of the EAI domain. Each facet contains a relative meta-model that utilizes widely-adopted standards. Finally, we demonstrate the utilization of ENIO in a real-world B2B scenario across a franchisor-franchisees collaborative value network.

The structure of this paper is as follows: in the following section, we present the goals, the role, the structure and the formalism of the ENIO, while, in section 3, we describe the utilization of each facet of the ENIO within the scope of an integration scenario across a franchisor-franchisees collaborative value network. We overview related work in section 4 and conclude with further work and concluding remarks.

2 THE ENTERPRISE INTEROPERABILITY ONTOLOGY

In order to provide formal specification and analysis of B2B integration scenarios, the data, services and processes that exist within an application integration problem should be defined formally and explicitly. The Enterprise Interoperability Ontology (ENIO) that we propose represents an explicit specification of the conceptualization of the EAI domain, and structures and formalizes the procedural and operative knowledge needed to describe and resolve the given EAI problem.

The ENIO Ontology has a three-fold focus: 1) to resolve most message level heterogeneities through the formal definition of the data (-types) in the input and output messages of a service, providing a reference model of data semantics; 2) to enable effective search and discovery of services through the formal representation of the capabilities and the functionality of service operators; and 3) to assist manual process composition through (reusable) process templates (Bouras et al., 2007).

The above-mentioned goals of ENIO constitute the basis for the identification of the dimensions and the structure of the ontology. We have chosen to introduce the

model of an upper ontology, which covers generic and domain-independent concepts, with several, domain-related extensions that we call facets. We have developed a three-faceted structure for ENIO: data facet; functional facet and process facet. In the following sections, we present the upper level of ENIO as well as the various facets.

We have decided to define an **Upper Ontology** for ENIO because: a) it provides a reference point and a framework for analyzing, harmonizing, and integrating existing ontologies and metadata standards; b) it provides a starting point, a predefined set of ontological entities and a ontology design pattern for building new, lower-level, domain ontologies; and c) a carefully engineered upper ontology, used as an ontology modelling basis, avoids the typical shortcomings, i.e. conceptual ambiguity and loose design, of commonly built ontologies (Oberle, 2006).

As analytically described in (Bouras et al., 2007), we are using in ENIO an alignment of DOLCE and SUMO that combines their advantages by including a core ontology (based on DOLCE) and a domain-independent ontology (based on SUMO) to establish the basic layers. The implementation of our upper ENIO Ontology is based on Smart SUMO (Oberle et al., 2006). To align SUMO to DOLCE, we pruned the upper-level of the SUMO taxonomy and aligned the remaining concepts to the appropriate DOLCE categories. During the alignment, it became apparent that grasping the intended meaning of SUMO's terms is quite difficult because of the loose merging of several theories in SUMO. Finding the best fitting super-concept in DOLCE for a SUMO term was therefore non-trivial. In addition, the design patterns of DOLCE, such as the design pattern for modelling qualities of endurants via regions, had to be taken into consideration when performing the alignment.

The **Data Facet** of ENIO aims to formally capture the semantics of messages exchanged among collaborative enterprise applications that expose their functionality as web services. The data facet facilitates dynamic data mediation by enabling the design of mappings and XSLT transformations for all service message elements (i.e. inputs and outputs) utilizing the schemaMapping attribute as in (Nagarajan et al., 2006). Two types of mappings between Web Service message elements and semantics have been identified (Nagarajan et al., 2006; Farrell & Lausen, 2006): a) mapping from the Web Service message element to the ontology concept, also called the "up-cast" and "up-level", and b) transformation from the ontology concept to the message element, called the "down-cast" and "down-level". Once the transformations are defined, two collaborative Web Services can interoperate by reusing these mappings, at run-time. As we do not intend to re-invent the wheel, we based the ENIO Data facet on the Core Components Technical Specification (CCTS). CCTS is currently the ISO 15000-5 Technical Specification and is supported and used by more than 50 projects and initiatives (including UBL and RosettaNet). The meta-model of the ENIO Data Facet ontologizes the meta-modelling elements of CCTS, i.e. Core Components (CC), Data Types, Aggregated CC, Basic CC and Association CC. For the population of the Data Facet, we have utilized as knowledge sources the following standards and vocabularies: the OASIS ebXML Core Components Dictionary, the RosettaNet Business Dictionary, the OAGIS specification and the OASIS Universal Business Language (OASIS UBL).

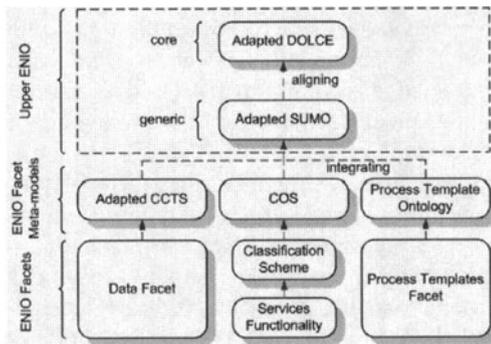


Figure 1 – The ENIO Conceptual Structure

The **Functional Facet** of ENIO defines the capabilities of enterprise services and provides classes for the annotation of services operators with functional semantics. This categorization of the intended functionality of the services combined with ontology-driven match-making algorithms may support efficient and effective discovery of published services in a business services registry. Furthermore, the Functional Facet of ENIO aims to assist manual process design, as the participation of a specific service in a business process composition scenario involves mainly the formal specification and shared understanding of its desired functionality. Our meta-model of the Functional Facet utilizes the Core Ontology of (Web) Services (COS), which is a module of the DOLCE foundational ontology.

The purpose of the **Process Facet** of ENIO is to provide means for defining collaborative business process templates and for annotating the states of Web Services with interior behavioural models that may be utilized in semi-automatic goal-driven composition. For the meta-model of the ENIO Process Facet we developed a process template ontology that follows the MIT Process Handbook methodology (Malone et al., 2003) to compose reusable process templates and includes the definitions of public views of processes and their variants, e.g. the “CRM Sales Order Processing” is a variant of the public process “Sales Order Processing”. Moreover, the ENIO Process Facet meta-model classifies each public view of a process under a specific category, associates them with tasks of the Functional Facet and assigns them with exactly one role, e.g. the previously mentioned public process “CRM Sales Order Processing” is classified under the “Sales and Services” category, and is associated to a task variant of the Functional Facet class “Sales” and to the “Sales Representative” role.

Figure 1 gives a bird’s eye view of the **ENIO structure**. In this paragraph, we describe the **ontology formalism** we selected for the development of ENIO. As our goal is to provide a general reference ontology for a semantically-enriched B2B EAI solution, a fine-grained axiomatisation is not needed. A semi-formal ontology providing a common vocabulary with a formal taxonomy, but without detailed logical axioms is enough for our purposes. We therefore chose a common denominator of ontology features which are present in all current ontological formalisms, including but not limited to RDFS, OWL, and WSML. The features we use are the following: concepts with formal sub-concept relation, instances with formal instantiates relation, and binary properties with single concept domain and range constraints. We have chosen OWL-DL as our implementation language

because it is an already available W3C recommendation and has good tool support. Moreover, other ontology formalisms (including WSML) provide conversion utilities from and to OWL-DL. We therefore expect that ENIO can be (semi-) automatically translated into various other formats in the future, if it is needed by the target application domain.

3 THE ENIO USAGE WITHIN A COLLABORATIVE VALUE NETWORK INTEGRATION SCENARIO

Assuming a typical franchisor-franchisees value-added network, we can identify a complex IT infrastructure in the franchisor headquarters comprising several centralized, corporate systems, i.e. ERP, CRM and WMS, which are required for the coordination of the retail activity, reimbursements, logistics and the pricing policy of the chain of retail stores. On the other hand, the Point-of-Sales (PoS) retail stores should be equipped with an ERP-like Retail System that will allow the collaboration with the franchisor and will facilitate the business activities of the value network.

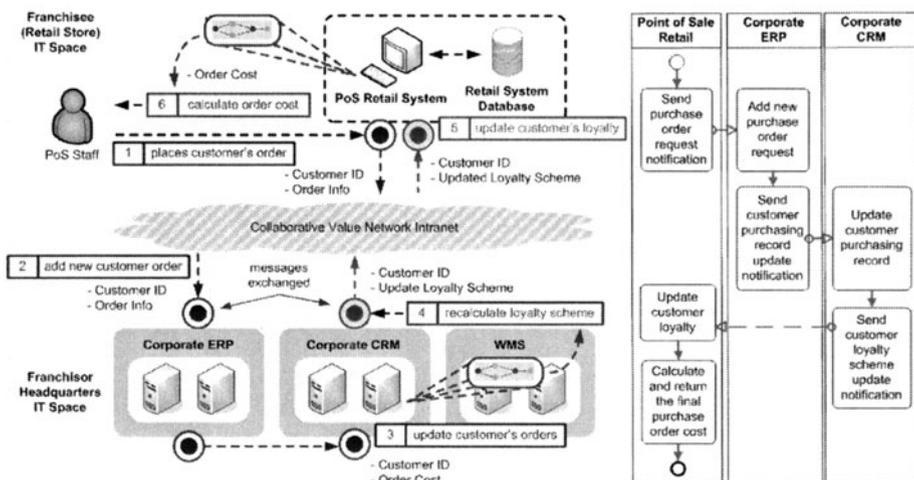


Figure 2 – Update Customer Loyalty Scheme CBP

In this enterprise context, we have identified several Collaborative Business Processes (CBPs) that compose and invoke (complex) services exposed from heterogeneous business systems. We have selected the “Update Customer Loyalty Scheme” CBP, so as to provide paradigms and demonstrate the usage of ENIO in facilitating the smooth integration of business processes in a dynamic environment. The selected CPB involves the calculation of the final cost (e.g. after discount) of a customer’s order, based on the customer’s loyalty scheme, which is dynamically reconfigured taking into consideration the current order, real time (see Figure 2 for more details).

The realization of the B2B integration scenario comprises two stages: a) the identification and the semantic uplifting of the involved Web Services, and b) the manual composition of the respective business process. A set of four public (non-internal) Web Services have been identified: 1) Place Order (POS Retail), 2) Add New Order (Corporate ERP), 3) Update Customer Order Record (Corporate CRM),

and 4) Update Customer Loyalty (POS Retail). Following the SAWSDL annotation mechanisms, i.e. the modelReference, (Farrell & Lausen, 2006), we have introduces semantics in the syntactic description of the Web Services, utilizing the ENIO Data Facet concepts for the semantic uplifting of the Web Services input and output messages and the ENIO Functional Facet concepts for the representation of the services' operators. Tables 1 and 2 depict the semantic annotations of the first two identified services, i.e. Place Order (POS Retail), and Add New Order (ERP).

Table 1 – SAWSDL Annotations for the Place Order PoS Web Service

```

<wsdl:message name="RequestMessage">
  <wsdl:part name="custID" element="CustID"
    sawSDL:modelReference="http://.../ENIO/DataFacet.owl#Customer"/>
  <wsdl:part name="orderInfo" element="OrderInfo"
    sawSDL:modelReference="http://.../ENIO/DataFacet.owl#OrderInfo"/>
</wsdl:message>
<wsdl:portType name="PlaceOrder">
  <wsdl:operation name="placeOrder ">
    <wsdl:input message="RequestMessage" />
    <sawSDL:attrExtensions
      sawSDL:modelReference="http://.....#CustomerPlaceOrder"/>
    </wsdl:operation>
</wsdl:portType>

```

Table 2 – SAWSDL Annotations for the Add New Order ERP Web Service

```

<wsdl:message name="RequestMessage">
  <wsdl:part name="custID" element="CustID"
    sawSDL:modelReference="http://.../ENIO/DataFacet.owl#Customer"/>
  <wsdl:part name="orderInfo" element="OrderInfo"
    sawSDL:modelReference="http://.../ENIO/DataFacet.owl#OrderInfo"/>
</wsdl:message>
<wsdl:message name="ResponseMessage">
  <wsdl:part name="cost" element="cost"
    sawSDL:modelReference="http://.../ENIO/DataFacet.owl#OrderCost"/>
</wsdl:message>
<wsdl:portType name=" AddNewOrder">
  <wsdl:operation name="addNewOrder">
    <wsdl:input message="RequestMessage" />
    <wsdl:output message="ResponseMessage" />
    <sawSDL:attrExtensions
      sawSDL:modelReference="http://.....#CustomerPlaceOrder"/>
    </wsdl:operation>
</wsdl:portType>

```

By the time the semantic uplifting of the involved services is completed and all the relative up- and down- casting, i.e. XSD2OWL and OWL2XSD, XSLT transformations, are created, we utilize the third facet of ENIO, i.e. the Process Template Facet, so as to retrieve and customize a relative process template towards the development of the “Update Customer Loyalty Scheme” abstract process template. For the Abstract Process Template formulation, apart from the flow elements, we utilize concepts of the ENIO Functional Facet to formally define the desired functionality of a service required and concepts of the ENIO Data Facet to specify the interoperable terms exchanged among collaborative services (see Figure 3). To move from the abstract, semantically-enriched process model to the

“executable” process, we have to fill in this process skeleton with grounded Web Services that have been already semantically uplifted and meet the “requirements” of the abstract templates in terms of functionality required and input and output message types supported. Finally, as shown in Figure 3, the up- and down- casting transformations are utilized during execution time and facilitate the creation of XSD2XSD transformations among collaborative services, ensuring this way dynamic data mediation during run-time.

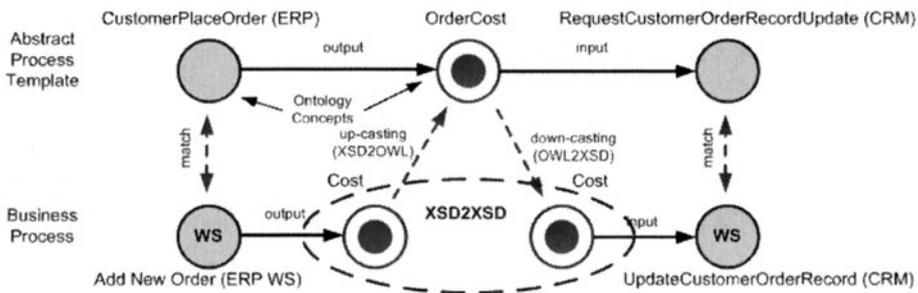


Figure 3 – Update Customer Loyalty Scheme CBP

4 RELATED WORK

There already exist some research initiatives that utilize semantics in EAI. For example, (Haller et al., 2005) have proposed to extend the notion of Service-Oriented Architectures by WSMO-based Semantic Web Services and showed how EAI benefits by it. On the other hand, (Izza et al., 2005) proposes an Ontology-Driven Service-Oriented Integration (ODSOI) that aims to extend the current web services stack technology by a semantic layer offering semantic services that can define the service semantics and also perform semantic mediation in the context of EAI. Finally, (Tektonidis et al., 2005) presents the creation of the ONAR SOA-based integration framework that enriches the semantics of the exchanged information and utilizes web ontologies to create semantic conceptualizations of the business concepts that exist inside an application.

None of these efforts, however, provides an integrated approach and a standards-based ontology to address dynamic data mediation and to facilitate service discovery and composition for business integration.

5 CONCLUSIONS AND FUTURE WORK

In this paper we have proposed an Enterprise Interoperability Ontology (ENIO) which comprises a foundational, upper-level EAI ontology, based on the alignment of DOLCE and SUMO, with extensions that cover several dimensions (facets) of the EAI domain, containing meta-models based on widely-adopted recommendations and research efforts (i.e. CCTS, COS). The upper level of ENIO has 159 classes and 90 properties, the data facet consists of 337 classes and 772 properties and the functional facet is made up of 256 classes. ENIO is available online at: <http://www.imu.iccs.gr/projects/fusion/ontology/>.

Moreover, we have presented the utilization of all facets of ENIO in a realistic B2B integration scenario within a franchisor-franchisees collaborative value network,

comprising complex, heterogeneous systemic infrastructure. In the frame of this scenario, we have demonstrated the dynamic resolution of data heterogeneities at execution time and the semantically-assisted business process composition supported by adequate discovery of exposed enterprise services.

Our current work refers to the use of ENIO with a semantic web service-based framework that facilitates the resolution of data heterogeneity problems and assists in service discovery and manual composition in EAI. Furthermore, we are currently working towards the state-related extensions of the Upper ENIO part that will facilitate the annotation of the internal behavioural model of complex services, which are potentially utilized in semi-automatic process composition scenarios.

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